PATENT
XER20404
D/A0125Q

TITLE OF THE INVENTION

INTELLIGENT COLOR TO TEXTURE CONVERTER

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The invention relates to the art of image rendering. It finds application where color images are rendered with a single colorant. For example, the invention finds application in repro-graphic machines where a color image is scanned and then transformed for rendering so that black and white copies of the color image can be made. The invention finds further application in general-purpose computing devices such as personal computers and business graphics authoring devices. In the latter devices, color images, such as, for example, bar and pie charts are created in color and displayed on a computer display. Thereafter, single colorant versions of the color images may be printed on, for example, black and white printers.

2. DESCRIPTION OF RELATED ART

Communicating concepts and ideas to others can be difficult. One method often used to communicate ideas to a group of people is to make a visual presentation. In a visual presentation, images such as charts, graphs and photographs are often displayed before an audience while a speaker explains and describes the significance of the images. Alternatively, the images can act as summaries of an associated speech. Typically, the images are presented in color. Color often adds to the impact and clarity of an image. For example, a pie chart or a bar graph is easier to read if its various sections are presented in different colors.

Copies of visual presentation material are often distributed to the audience members. The distributed materials serve to document the presentation. The distributed material can help audience members follow the presentation and can serve as a study aid or reference material.

Unfortunately, it can be impractical or prohibitively expensive to distribute a large

number of color copies of presentation material. Furthermore, in some cases, color reproduction equipment is not readily available. In these cases the color images are often reproduced in black and white.

Creating black and white versions of color images can be problematic. Typically, a great deal of information is lost in the conversion to black and white. For example, typical color image authoring devices can produce over sixteen million different colors, while typical black and white rendering devices can only produce two hundred fifty six shades of gray. Obviously, a great number of colors must be mapped to each level of gray. Therefore, portions of a color image that are quite obviously different colors can appear to be the same color when the image is rendered in black and white. When the image portions in question are, for example, different sections of a pie chart or bar graph, this loss of information can render the chart or graph useless.

Attempts have been made to alleviate this problem by using texturing to increase the number of ways colors can be represented in a black and white image. For example, one texturing or patterning technique is described in U.S. Patent 4,903,048 to Harrington. Typically, under these strategies, the conversion to black and white is accomplished by dividing a color space into a finite number of bins and assigning a different halftone pattern to each of the bins. This approach does preserve more information from the color image. However, this approach can lead to abrupt transitions in the black and white image, which may not be desired in some applications. In this regard, where colors in the original image smoothly blend from one color to another, the blend in color can cross a bin boundary, resulting in a sudden shift in a halftone pattern or level. This situation can be further aggravated by the presence of noise in the image. For example, a subtle jitter or shift in the color in a photograph of a persons face can be transformed into dramatic changes in halftone patterns if the jitter or shift is across one or more bin boundaries.

All halftoning methods by definition introduce some distortion in the output image. Designers of halftoning methods typically make tradeoffs in representing the visual parameters of spatial detail versus tonal fidelity. The additional requirement to represent color statically in the halftone pattern reduces the capability of the halftoning system to represent the two visual parameters. For this reason, where these techniques are used, they are generally not available in “walk up mode”. Therefore, prior art image processors often have controls for various modes of operation which set tradeoffs between the visual parameters and the addition texture related features. The use of these controls puts an

additional cognitive load on the "walk up" or casual users. The user must know the features are available and know how to use them. Thus it is a great advantage if the image processor can make intelligent choices on when and where to make the tradeoff of color representation. A method of generating black and white versions of color images is needed that preserves as much information as possible from an original color image, while minimizing the amount of distortion introduced into the black and white image. Furthermore, a method is needed that is invoked automatically when a particular image requires the use of the method, and then, only at points in the image that require it, thus providing "walk up mode" availability of the method.

BRIEF SUMMARY OF THE INVENTION

To those ends, a method for rendering an image, described in a multi-colorant color space, in a single-colorant color space has been developed. The method comprises the steps of examining the image to find conflicting colors in the image, creating a single colorant version of the image, and adding texture only to portions of the single colorant version of the image that are associated with the conflicting colors.

One embodiment of the method comprises the steps of collecting histogram information from the color image wherein bins within the histogram classify image pixels based, at least in part, on luminance and hue information, classifying peaks within the histogram that have similar luminance as conflicting colors, and applying modulation to at least some of gray scale versions of the conflicting colors thereby making the gray scale versions visually distinguishable from one another.

An image processor operative to carry out the method comprises an image analyzer operative to find and classify conflicting colors in a color image and a gray scale modulator operative to add modulations to gray scale versions of only the conflicting colors within a gray scale version of the color image.

In one embodiment, the image analyzer includes a histogram collector operative to classify pixels in the color image based, at least in part, on a characteristic that is also used to generate a single colorant version of the color image. The image analyzer also includes a conflicting color detector operative to examine the histogram and find pixels that are similar with respect to the characteristic that is used to generate a single colorant version of the image. The characteristic is, for example, a pixel luminance. The gray scale modulator includes a color relationship discriminator operative to receive conflicting color

classification information from the image analyzer and color image pixel information. The gray scale modulator determines a relationship between the color image pixel and the conflicting color. The gray scale modulator further includes a modulation generator operative to add a variable gray scale modulation based on the relationship between the color image pixel and the conflicting color. The added modulations are applied to gray scale versions of the conflicting colors.

One advantage of the present invention is that it provides a method to add distinguishing texture to a black and white version of a color image only where the modulation is required.

Since, by the very nature of the present invention it only operates when it is absolutely necessary, an image processor operative to carry out the method can do so in a "walk up" or default mode of operation. This provides the advantage of freeing an image processor user from having to know about and manually invoke the method. Instead the method is invoked all the time and only operates to adjust an image when it is needed.

Another advantage of the present invention is the minimal distortion it adds to black and white versions of color images while maximizing information preservation.

Still other advantages of the present invention will become apparent to those skilled in the art upon a reading and understanding of the detail description below.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments, they are not to scale, and are not to be construed as limiting the invention.

FIGURE 1 is a black and white version of a color 3-dimensional bar graph rendered with a prior art image processor using a prior art method;

FIGURE 2 is a black and white version of a color pie chart rendered with a prior art image processor using a prior art method;

FIGURE 3 is a flow chart outlining an intelligent method for generating a single colorant version of a multicolor image;

FIGURE 4 – FIGURE 7 are representative samples taken from an exemplary 3-dimensional histogram used in an embodiment of the method of FIGURE 3;

FIGURE 8 is a block diagram of an embodiment of a color image processor

operative to perform the method of FIGURE 3;

FIGURE 9 is a black and white version of the color 3-dimensional bar graph referred to with reference to FIGURE 1, rendered with the method of FIGURE 3; and

FIGURE 10 is a black and white version of the color pie chart referred to with reference to FIGURE 2, rendered with the method of FIGURE 3.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGURE 1, a prior art image processor produces a prior art, black and white version **110** of a first color business graphic (not shown). The first color business graphic is a 3D bar graph representing, for example, first quarter sales by region. In the color version, a western region bar is rendered in, for example a dark yellow, a central region bar is rendered in, for example, a dark green, a southeast bar is rendered in, for example, a dark blue, and a northeast region bar is rendered in, for example dark red. In the prior art black and white version **110,** a western region bar **114** is rendered in a very light gray. A central region bar **118** is rendered in a dark gray. A southeast region bar **122** and a northeast region bar **126** are both rendered in a medium gray. The medium gray is the same for both bars **122, 126**. Bars that were originally visually distinct by virtue of being rendered in blue and red respectively now appear related. A viewer of the prior art black and white version **110** of the image is left wondering if the southeast **122** and northeast **126** regions are related in some way that the western **114** and central **118** regions are not. The viewer wonders, "If the southeast and northeast regions are not related, then why did the image author choose to render the bars **122, 126** with the same shade of gray?" The information lost due to the prior art image processing technique has rendered a clear and concise image confusing and aggravating.

Referring to FIGURE 2, a prior art image processor produces a prior art, black and white version **210** of a second color business graphic (not shown). The color business graphic is a pie chart representing, for example, dairy revenue by region, further broken down by item classification. Each classification is represented in a pie wedge. In the color version, item classes are coded in different colors. For example, dairy items are coded in yellow, notions are shown in pink, bakery items are represented by navy blue, grocery items are indicated in blue, meat is illustrated with a reddish-orange and produce is rendered in green. In the prior art, black and white version **210** the various item classification are depicted in various shades of gray. The Notions **214** and Meat **218**

categories are depicted in the same shade of gray. Additionally, the grocery **222** and produce **226** categories are depicted in shades of gray that are very similar. As a result, the viewer cannot tell which wedge represents notions **214** and which wedge represents meat **218**. Additionally, the viewer must struggle to determine which wedge represents grocery **222** revenue and which wedge represents produce **226** revenue. Wedges that were originally visually distinct by virtue of the colors the wedges were rendered in, are indistinguishable in the prior art, black and white version **210** of the chart. Again, the information lost due to the prior art image processing technique has rendered a clear and concise image confusing and aggravating.

Referring to FIGURE 3, an intelligent method **310** for generating a single colorant version of a multicolor image comprises an image examination step **312** and a single colorant version creation step **314**. In the image examination step, the image is examined to find conflicting colors in the image. In the single colorant version creation step **314,** a single colorant version of the image is created wherein texture is added, preferably, only to portions of the single colorant version of the image that are associated with the conflicting colors.

One embodiment of the image examination step **312** begins with a histogram collection step **316**. The purpose of the histogram collection step is to group and count image pixels based on a characteristic of interest. For example, pixel luminance is used in transforming color images to black and white images. Therefore, pixel luminance is a characteristic of interest. The well-known Commission International de l'Eclairage or International Commission on Illuminations L*a*b* color space (CIELAB) maps colors in a machine independent, perceptually uniform, three-dimensional color space. One of the dimensions is luminance (L*). CIELAB is a convenient color space to use when luminance is a pixel characteristic of interest. The other two dimensions, a* and b* describe a colors hue. When the colors in an image are described in the CIELAB color space it is convenient to analyze them using a three dimensional histogram. Every occurrence of a particular L*a*b* color is counted. For example, every time an image pixel is found that has the pixel value L*=157, a*=77, b*=146 a corresponding counter is incremented. Likewise, counters corresponding to other pixel values are incremented for each occurrence of pixels of those values. In a peak location step **318,** the histogram is examined to find colors that predominate in or make up major portions of the image. When found, these colors are identified and classified as peak colors or color centroids.

For example, where pixels of a particular color make up more than a threshold percentage of the image, they are classified as belonging to a peak color. Alternatively, the location of a color centroid -- which is a function of the location and height of a peak, as well as the number, height and location of neighboring peaks -- could be used (as described below) to classify pixels as belonging to a particular peak color. In a peak association step **322,** peak colors that share the same or similar luminance are associated with one another and labeled as conflicting colors. Typically, the definition of "similar luminance" is a function of a perceived gray scale capability of a target image-rendering device. For example, different colors may be said to have a similar luminance (or other characteristics of interest) if the target image-rendering device would render a single colorant version of the colors so that the single colorant versions of the colors would be difficult for an observer to distinguish.

One embodiment of the single colorant version creation step **314** begins with a modulation association step **326,** wherein a modulation is associated with each of the conflicting colors. The modulations are to be applied to single colorant versions of the colors. For example, colors with the same luminance are transformed to the same level of gray for rendering in black and white. As illustrated in reference to FIGURE 1, this often leads to the unacceptable result that image portions that are quite distinctly different colors are rendered as the same shade of gray. However, where this embodiment of the intelligent method **310** for generating a single colorant version of a multicolor image is used, the modulation association step **326** assigns a modulation, such as, for example, a unique pattern, to each conflicting color. For example, a unique screen such as a unique line screen can be applied to the single colorant, or black and white version, of each conflicting color. In a color distance measurement step **330,** a relationship between the conflicting colors and image pixels is determined. Preferably, a perceptually uniform color space is used as the basis for comparing colors. For example, the CIELAB color space is used to compare colors in the image. One way to compare colors is to measure a distance between the peak colors and the colors of image pixels. Methods of measuring a distance between colors in a color space are known in the art. For example, the equation $D=\Delta L^2+\Delta a^2+\Delta b^2$ is used to measure the distance between colors in the CIELAB color space. The measured distances are recorded in association with the image pixels. In a modulation application step **334,** modulations are added to the single colorant or gray scale versions of the image. For example, an image pixel is assigned the modulation pattern of the closest conflicting peak. The amplitude of the modulation is a function of the color

distance of the pixel to the conflicting peak color. For example, pixels that are the same color as a conflicting color are modulated at one hundred percent of the modulation assigned to that conflicting color. Colors that are nearby a conflicting color are also modulated with the modulation assigned to that conflicting color. However, the modulation is applied at a reduced amplitude. For example, based on a color's distance from a conflicting color, a black and white version of the color might be modulated only forty percent of the modulation amplitude assigned to the conflicting color. Preferably, the amplitude of modulation rolls off quickly. Such steep roll offs are achievable with steep slope linear attenuation functions. However, non-linear functions can also be used. One reason for modulating colors beyond the single peak color is that printed colors that appear to be one uniform color can actually be made of up a range of colors. In such a case, it is preferable to modulate all the component colors. Additionally, imperfections in scanning equipment can result in pure image tones being recorded as a range of colors.

For example, referring to FIGURES 4–7, first **410**, second **414**, third **418**, and fourth **422** portions of a histogram of a business graphics image show the image comprises only a small number of clusters of colors. Each portion **410, 414, 418, 422** of the histogram represents a different range of levels in a characteristic of interest. The characteristic of interest is used in the generation of a single colorant or gray scale version of the image. For example, each portion **410, 414, 418, 422** of the histogram represents a first **423,** second **424,** third **425** and fourth **426** range of luminance or gray levels respectively. At each range of luminance or gray levels **423, 424, 425, 426** the color of pixels is further described by values in a* and b*. The a* and b* scales are broken down into, for example, sixteen subsections. Therefore at each luminance level range (L*) pixels are further classified into one of two hundred fifty six bins. Each bin represents a small range of a*b* values. In an embodiment of histogram collection step **316,** each pixel in the image is examined and the bin corresponding to an L*a*b* value of the pixel is incremented. Each number shown in the histogram portions **410, 414, 418, 422** represents the final tally in a bin.

In an embodiment of peak location step **318,** the histogram is examined in order to find peaks and/or clusters of predominant image colors. For example, referring to FIGURE 4, the bins of the first histogram portion are compared, for instance, to a peak definition threshold. For example, bins having a final tally of over ten thousand are considered to identify colors that represent a significant portion of the image. Ten

thousand is given as an example only. Typically, a peak definition threshold is determined based on the number of pixels in the image. None of the bins in the first histogram portion **410** contain a tally over ten thousand. Therefore, none of the colors represented by first histogram portion **410** bins are labeled as conflicting peaks.

Referring to FIGURE 5, the second histogram portion **414** is also examined. A first peak bin **428** is determined to contain a tally that exceeds the peak definition threshold. For example, the first peak bin **428** contains a tally of 16,135, which is greater than the peak definition threshold of 10,000. However, no other bins in the second histogram portion **414** contain tallies that exceed the peak definition threshold. Therefore, none of the colors represented by first histogram portion **414** bins are labeled as conflicting peaks.

Referring to FIGURE 6, the third histogram portion **418** is examined. Second **430**, third **434** and forth **438** peak pins are located and determined to contain tallies above the peak definition threshold. The third histogram portion **418** contains more that one peak bin. Therefore, in a peak association step **322,** each third histogram portion **418** peak bin **430, 434, 438** is labeled a conflicting peak and histogram examination continues.

Referring to FIGURE 7, the fourth histogram portion **422** is examined. Fifth **440,** sixth **444** and seventh **448** peaks are identified. Since the fifth **440**, sixth **444** and seventh **448** peaks are in the same histogram portion **422,** they are labeled as conflicting peaks.

In some embodiments of the peak association step **322**, the definition of a peak may be adjusted. For example, in some embodiments, peaks are located in exact correspondence to the location of each bin that exceeds the peak definition threshold. In other embodiments, the location of peaks is adjusted to take into account the tallies in neighboring bins. For example, in some embodiments, the tallies and locations of neighboring second **430** and third **434** peak bins are combined to define a first centroid peak located in color space at a point between the locations of the second **430** and third **434** peak bins. For example, the first centroid is located in color space at a tally-weighted distance between the second **430** and third **434** peak bins. For example, the first centroid is located four tenths of the way from the second peak **430** to the third peak **434**. The first centroid is located closer to the second peak **430** because the second peak **430** tallies sixty percent of the pixels represented by the combination of the second **430** and third **434** peaks. The location of the centroid may also be influenced by neighboring bins in neighboring histogram portions. For example, first **430**, second **434**, fourth **440** and fifth

444 peak bins may be combined to define a second centroid located in color space between the first **430**, second **434**, forth **440** and fifth **444** peak bins not only within an a*b* plane, but also between a*b* planes of different but neighboring gray levels. In still other embodiments the definition of a peak or centroid is further modified to take into account an influence of non-peak bins that neighbor peak bins. Furthermore, the effect of a chain or cluster of non-zero bins can also be taken into account. For example, with reference to FIGURE 6, the influence of a first non-peak bin **450** is accounted for in some embodiment because a chain of non zero bins including second **452**, third **454**, fourth **456** and fifth **458** non-peak bins tie the first non-peak bin **450** to the third **434** and second **430** peak bins. Chains can also extend across histogram portions. Consideration of chained non-peak bins is not preferable. Where it is used, limits are usually placed on the length of the chain. For images that contain very few or zero bins, such as, for example, images that contain full color photographs, these limits help prevent the detrimental extension of chains throughout the entire histogram.

In whatever way peaks are defined, at the end of the peak association step **322,** peaks with similar characteristics of interest, such as, for example, peaks with a similar luminance, are labeled as conflicting with each other. Modulations are associated with the conflicting colors, attenuation factors are determined for colors near the conflicting colors in color space, and attenuated modulations are added to gray scale versions of the conflicting colors to generate a single colorant version of the image.

In summary, there are a number of ways to define the location or color of a peak. For example, once a cluster is defined around a peak, the statistical mean location of the cluster's pixels in L*a*b* space can be calculated. Under this system, the color distance of step **330** can be measured in standard deviations from the mean. Alternatively, the peak in any cluster may be simply defined as the bin location tallying the largest number. In that case, the color distance of step **330** can be measured in, for example, bin index increments. However color distance is measured, it is used as an attenuation control signal in the modulation application step **334** in order to add varying degrees of modulation to component pixels of a conflicting clusters or peaks.

Image processors, such as, for example, document processors, copiers, and personal computers, operative to perform the intelligent method **310,** for generating a single colorant version of a multicolor image, take many forms. Such an image processor can be analog or digital, hardware based or software based, or based on any combination

of those technologies and others. Referring to FIGURE 8, one image processor **804** operative to carry out the intelligent method **310** for generating a single colorant version of a multicolor image comprises an image analyzer **808** and a gray scale modulator **812.** The image analyzer **808** is operative to find and classify conflicting colors in the color image. The gray scale modulator **812** is operative to add modulations to gray scale versions of only the conflicting shades within a gray scale version of the color image. In this exemplary embodiment, the image analyzer **808** comprises a histogram collector **814**, a peak locator **818**, and a conflicting color detector **822**. The gray scale modulator comprises a plurality of distance measurers **834**, a plurality of modulation generators **838** and a plurality of modulation attenuators **842.** The image processor also includes a page buffer **846**, a gray scaler **850**, a summer **854** and an image receiver **858**. The histogram collector **814** and the page buffer **846** each receive a copy of the image. Typically, the page buffer **846** holds the image while the histogram collector **814**, peak locator **818** and conflicting color detector **822** analyze the image. The histogram collector **814** fills an array with pixel count information.

For example, in a system operating in CIELAB space, the histogram collector **814** defines and fills a three dimensional array. The indexes or dimensions into the array are L*, a* and b*. Each pixel in an image is analyzed to determine the pixels L*, a* and b* values. The L*, a* and b* values are used as indexes into the array and the value of that array location is incremented. This process is repeated for every pixel in the image. When every pixel has been accounted for, access to the array information is granted to the peak locator **818**. The peak locator scans the array and looks for array locations containing values that exceed a threshold value. The threshold value can be fixed or it can vary depending on image size or some other parameter. The index values (L*, a*, b*) of array locations that contain values above the threshold value are recorded and presented to the conflicting color detector **822** as, for example, a list of peaks. The conflicting color detector **822** searches for clusters of peaks that have the same or similar luminance values (L*). Peaks that belong to such clusters are labeled conflicting colors and are added to a conflicting color list. Peaks that are not labeled conflicting colors are dropped from consideration and are not candidates for modulation. The location in color space (L*a*b*) of each conflicting color is loaded into a distance measurer **834**. Additionally, a modulation generator **838** is assigned to each conflicting color. The distance measures **834** examine each pixel in the image in the page buffer **846** and deliver adjustment signals to

associated modulation attenuators **842.** The adjustment signals are based on the measured color distance between the conflicting colors and the examined pixels. Each modulation attenuator **842** receives a modulation signal from one of the modulation generators **838** and delivers an attenuated version of the modulation signal to the summer **854.** The amount of attenuation imposed by a particular modulation attenuator **842** is a function of the attenuation signal delivered from an associated distance measurer **834**. Modulation attenuation can range from zero to one hundred percent. Therefore, each modulation attenuator **842** can deliver a one hundred percent to zero percent modulation signal to the summer **854**. The summer also receives gray scale image pixel information from the gray scaler **850.** The gray scaler **850** in turn receives color pixel information from the page buffer **846.** In general, the gray scaler **850** creates gray scale pixels based on a characteristic of interest of the color pixels in the page buffer **846**. In this particular case, the gray scaler **850** creates gray scale pixels based on the luminance of the pixels in the page buffer **846.** Gray scale pixel information leaves the gray scaler **850** in synchronization with the pixels being examined by the distance measurers **834**. Therefore, as gray scale pixel information enters the summer **854,** the summer is also receiving modulation signals appropriate for that gray scale information. The summer **854** combines the gray scale information with the modulation signals and outputs appropriate single colorant mark information. That information is delivered to the image receiver **858**. The image receiver **858** can be, for example computer memory, computer network, or a mass storage device such as a disk drive. Alternatively, the image receiver **858** can be a rendering device, such as, for example, a print engine or a monochrome monitor. The print engine may be, for example, a black and white printer such as, for example, a xerographic printer. Those of ordinary skill in the art will recognize that a xerographic printer comprises a fuser, a developer and an imaging member.

Referring to FIGURE 9, an image processor operative to perform the method of FIGURE 3 produces an improved black and white version **910** of the first color business graphic (not shown). In the improved black and white version **910,** a western region bar **914** is rendered in a very light gray. A central region bar **918** is rendered in a dark gray. A southeast region bar **922** and a northeast region bar **926** are both rendered in a medium gray. The medium gray is the same for both bars **922, 926**. However, the medium gray of the southeast region bar **922** is modulated with a downward sloping line screen and the northeast region bar **926** is rendered with an upward sloping line screen. Bars that were

originally visually distinct by virtue of being rendered in blue and red respectively are maintained as visually distinct by virtue of being rendered with visually distinct modulations. At the same time, colors that do not conflict **914, 918** are rendered in levels of gray without modulation. A viewer of the improved black and white version **910** of the color image is not confused. The distinctness of the southeast bar **922** and the northeast bar **926** is maintained.

Referring to FIGURE 10, an image processor operative to perform the method of FIGURE 3 produces an improved black and white version **1010** of the second color business graphic (not shown). As explained above, the second color business graphic is a pie chart. In the prior art black and white version of the image **210,** the notions **214** and meat **218** categories were depicted in the same shade of gray. In the improved black and white version **1010,** the shade of gray representing the notions **1014** category is modulated with 135-degree line screen and the meat **1018** category is modulated with a horizontal line screen. Additionally, the Grocery **1022** category is modulated with a 45-degree line screen and the produce **1026** category is modulated with a vertical line screen. As a result, the viewer can tell which wedge represents notions **1014** and which wedge represents meat **1018**. Additionally, the viewer is able determine which wedge represents grocery **1022** revenue and which wedge represents produce **1026** revenue. Wedges that were originally visually distinct by virtue of the colors of the wedges, are maintained as visually distinct, by virtue of modulation, in the improved black and white version **1010** of the chart. It should be noted that the modulations are exaggerated for clarity in FIGURE 10. Preferably, the effect of modulation is subtler. For example, FIGURE 9 depicts a preferable level of modulation.

The invention has been described with reference to particular embodiments. Modifications and alterations will occur to others upon reading and understanding this specification. For example, characteristics other than luminance can be used in the creation of single colorant versions of an image. Therefore, characteristics other than luminance can be used in the detection of conflicting colors. Methods and devices other than histograms may be used to find conflicting peaks. For example, color image pixels can be compared against a predetermined list of known conflicting colors. Likewise, look up tables of predetermined color distances can be used instead of the color distance measurers. Many other image processor implementations are contemplated for carrying out the method of intelligent color conversion. Hardware, software, neural networks,

application specific integrated circuits, programmable gate arrays and a host of other technologies can be used to implement versions of the image processor. It is intended that all such modifications and alterations are included insofar as they come within the scope of the appended claims or equivalents thereof.